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Investigations on Methods of Control of the Blue-mold Decay of Apples

by

Kenneth F. Baker and F. D. Heald

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
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[3] Temporarily transferred to U. S. Department of the Interior as Regional Director, Pacific Northwest Soil Erosion Control Project.
[4] On leave.

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Investigations on Methods of Control of the Blue-Mold Decay of Apples[1]

Kenneth F. Baker[2] and F. D. Heald[3]

INTRODUCTION

A considerable percentage of the blue-mold decay of Washington apples arises from infections at the lenticels (2). In a previous publication (4) it was shown that there is little hope of effective control of lenticel infections of apples by *Penicillium expansum* Link, or of reduction of total blue-mold decay, by modification of cultural practices. In this paper a method of partial sterilization of fruit is presented which is thought to be entirely practicable on a commercial scale, and its relation to the complete schedule of control is indicated.

MATERIALS, METHODS, AND RESULTS

Sanitation in the Packing Plant

The packing house is the main source of contamination of fruit with spores of *P. expansum*. The air of these plants has a heavier load of blue-mold spores than the orchard (23). This is largely due to the accumulation of some of the contamination of all the fruit and boxes passing through it, but there is also a development of the fungus in place. The organism commonly develops in crusts on timbers above the washing tank, the condensed steam furnishing moisture for growth; it also develops on leaves, pieces of apple, and other debris on the floor. These conditions are especially noticeable in basement packing plants or places with poor air circulation.

Only clean new boxes are used in Washington for marketing apples, and these are frequently used in harvesting as well. Broken and imperfect boxes, however, are repeatedly used for picking for

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[1] Includes portions of a thesis submitted to the Graduate School of the State College of Washington by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1934.

[2] Research Assistant in Plant Pathology, Washington Agricultural Experiment Station, Pullman, Wash.

[3] The cooperation of Prof. F. L. Overley in the field work in Wenatchee is gratefully acknowledged. The helpful suggestions and encouraging interest of Dr. H. F. Clements, Dr. L. K. Jones, and Dr. G. A. Huber during the progress of the investigation have been greatly appreciated.

several years, and some companies utilize an additional number of lug boxes for the same purpose. Huber (23) found up to 32,987,520 Penicillium spores (mainly *P. expansum*) on the inside surface of dirty boxes. This contamination is a result of the spores collecting on the surface and of the profuse development of the organism, especially when juice from injured apples is present. Thus, the boxes bring many spores into the packing plant.

The washing tank is contaminated by spores on the surface of apples passing through it, from spores in the air, and from occasional rotten apples passing through it (19). The importance of the washing tank in tending to equalize the spore load of all fruit passing through it, to the detriment of some lots and the benefit of others, has come to be generally recognized. The tendency to carry spores into injuries which might otherwise escape infection is marked, and is especially important because it also provides moisture for germination. It has been shown (3) that blue-mold spores are nearly all killed during the overnight stand under the present practices, and that the maximum contamination will be that accumulated in each day's run. Huber (23) has shown that the gloves of packers also serve as equalizers of contamination of apples. The conveying and handling equipment become heavily contaminated with blue-mold spores. This further serves to equalize contamination of the fruit.

Storage rooms of various types have large numbers of blue-mold spores (26, 30, 31, 32). Fruit packed in boxes or barrels is not contaminated by exposure to such conditions, but apples in bins or open boxes may be effectively inoculated by spores from the air. Blochwitz (8) found that barges bringing apples into Germany from Czecho-Slovakia were heavily contaminated by *P. glaucum* Link (*P. expansum*), and thought this was one of the main sources of inoculum of the fruit.

These facts make it apparent that the most effective place to practice intensive sanitation under Washington conditions is in the packing plant. It is important to know whether the spore load is cumulative from year to year, throughout the packing season, or for only comparatively brief periods (i.e. the longevity of the spores) to determine the need of disinfection.

Longevity of Blue-mold Spores. No published data on the longevity of spores of *P. expansum* have been found by the writers. This point has been investigated to some extent since 1931.

Blocks one inch square were cut from the sides of wooden apple boxes of about average cleanness. These were dipped in a suspension of spores of *P. expansum*[1] made from a seven-day-old culture on two

[1] The cultures used in the work reported in this paper were transfers from the strain used in previous work (3, 4).

per cent dextrose potato-agar on April 22, 1932. After drying for 24 hours in a culture room these blocks were placed in a clear glass bottle which was plugged fairly tightly with cotton and placed outdoors. The blocks were held until May 25, 1933 in a northern exposure outside the laboratory, protected from rain and snow. Washings were made of random-sample blocks at periodic intervals. Each block was scrubbed in 300 cc. sterile water with a sterile stencil brush (22) for a five-minute period. Two drops of this wash water were plated out in each of three Petri dishes and incubated. The blocks had about the usual contamination of organisms other than *P. expansum.* The results, given in Table 1, have been adjusted to the basis of spores per square inch of block.

Starting in April, 1932 there was no decrease in the number of viable spores during the hot months of June and July. By November there was a marked reduction; the cold period from the last of November to the last of January caused a further reduction, about 22 per cent remaining viable. By May 25, 1933 (398 days after the test was begun) only 0.5 per cent of the spores remained viable.

Table 1. Longevity of Spores of *P. expansum* on Blocks of Wood Held Outdoors from April 22, 1932 to May 25, 1933 at Pullman

Date of analysis	Time exposed	Number of spores per square inch on blocks at each time interval			
		Block 1	Block 2	Block 3	Average
April 23, 1932	1 day	——*	——*	——*	——*
June 27, 1932	66 days	58,100	51,100	29,400	46,200
July 19, 1932	88 days	65,800	63,000	——	64,400
Nov. 27, 1932	226 days	5,600	13,300	15,400	11,433
Jan. 30, 1933	284 days	7,000	1,400	19,600	10,200
May 19, 1933	392 days	33	33	——	33
May 25, 1933	398 days	100	330	230	238
		66	600	100	

*Too many to count.

Another test, in which blocks of wood were sterilized with dry heat previous to being dipped in the spore suspension on August 28, 1931 and held at laboratory temperatures, showed only a few spores surviving after 225 days. A somewhat smaller number, however, were viable after 521 days. There were none surviving after 630 days. It is thought that the volatile products arising from the wood as a result of the sterilization were responsible for the sudden sharp decrease in the spore load at the beginning of the test.

In a previous publication (4) a method was mentioned of securing uniform inoculum in field studies by using packets of blue-mold spores

mixed with dry sugar. Cultures of *P. expansum* were grown on two per cent dextrose potato-agar for several weeks and thoroughly dried at 32° C. The spores were scraped from the surface of the plate and mixed with dry sugar. This mixture was then divided into approximately equal parts and each wrapped in a separate piece of paper. By diluting these in a given amount of water a convenient and fairly uniform spore suspension could be obtained.

Such spore packets made on August 26, 1931 for use in the 1931 field work (4) have shown only slight diminution of viable spores in periodic tests down to March 21, 1934, a period of 938 days. While being carried about for field use in the late fall months of 1931 these packets absorbed moisture from the air, but were carefully dried again on November 20, and subsequently held in the laboratory.

Another series of packets made in the same way on August 25, 1932 had shown a slight reduction in the number of viable spores by October 27, 1933 (428 days later); by March 21, 1934 (573 days later) very few spores remained viable.

The spores were equally long-lived when retained on the two per cent dextrose potato-agar in Petri dishes. Such cultures made January 14, 1932, and held in the laboratory, soon became dry; periodic tests have shown no diminution of the number of viable spores by March 21, 1934, a period of 797 days.

In all of these tests there is a comparatively rapid increase of the number of viable spores at first, followed by a gradual decline to a few very resistant spores. This is evidence of the variability in resistance to be encountered in a uniform mass of spores.

The longevity of the spores on the picking boxes and handling equipment is an important point to be considered in the practice of sanitary measures. It is evident that the spores are rather long lived, and that the contamination of boxes and equipment will greatly increase during the operating season and to some extent from year to year. Also, the sporulation of the fungus in such places during moist periods greatly increases the contamination from season to season. Only by killing these spores by some means can the inoculum be kept at a low level.

Reduction of Contamination of Equipment. Sodium hypochlorite solutions are among the most promising materials for use in disinfecting equipment. Lewis and Yesair (26) and Race (33) have reviewed the literature on this subject.

Because hypochlorite solutions react with free organic matter greater amounts of them must be used when such material is present. However, the products of such reaction (e. g. the chloramines) also

exert a toxic effect. Lewis and Yesair (26, 27) found that spores of *P. expansum* were killed in three minutes in a sodium hypochlorite solution having 0.27 per cent available chlorine and ten minutes in a solution having 0.122 per cent available chlorine in the presence of organic matter (plain nutrient broth), but that a 0.0096 per cent solution was lethal in three minutes in the absence of organic matter. They found that surfaces of various pieces of equipment and of a cooling room showed a marked decrease in bacterial and fungous contamination five to ten minutes after spraying with hypochlorite solutions having from 0.379 to 0.51 per cent available chlorine. The use of such solutions having 0.4 per cent available chlorine following the usual cleaning of equipment was recommended.

Preliminary work in California (1) showed that chlorine and nitrogen trichloride were effective against fungi contaminating boxes, belts, and other equipment in citrus packing houses.

The effectiveness of three proprietary sodium hypochlorite solutions on suspensions of spores of *P. expansum* was studied preliminary to investigations on their use as sterilizing agents on packing equipment. The percentage of available chlorine was determined for each of the substances tested by the acetic acid method (35) against a N/10 sodium thiosulphate solution. Clorox[1] was found to have 5.08 per cent

Table 2. Number of Viable Blue-mold Spores per Cubic Centimeter Obtained at Intervals from Spore Suspensions in Sodium Hypochlorite Solutions at Room Temperature

Time of exposure	Chlorosan (Westochlor)			Zonite; 0.017% available chlorine	Clorox*; 0.017% available chlorine
	0.003% available Cl		0.03% available chlorine		
	Test 1	Test 2			
0 minutes	2093	1073	2337	2667	2680
5 minutes	——	——	——	2587	2710
10 minutes	——	——	——	140	2280
15 minutes	——	——	0	27	250
20 minutes	——	——	0	3	106
1 hour	——	4	0	——	——
2 hours	——	6	0	——	——
3 hours	——	0	——	——	——
6 hours	4	0	——	——	——
12 hours	0	0	——	——	——

* Data taken from Table 4 of Baker and Heald (3).

[1] Manufactured by Clorox Chemical Co., Oakland, California.

available chlorine. Chlorosan (now called Westochlor)[1] had 3.45 per cent, and Zonite[2] had 0.93 per cent.

Aqueous suspensions were made of spores from nine-day-old cultures of *P. expansum* grown on two per cent dextrose potato-agar, and sufficient sodium hypochlorite added to give the amounts of available chlorine indicated. One cc. of the mixture was taken at stated intervals, and after a 1/10 dilution was made, one cc. was transferred to a Petri dish and mixed with medium. Each of the figures in Table 2 is the average of three poured plates from each of three flasks.

While the rapidity of action was not so great in these studies as in those of Lewis and Yesair, the results indicate that sodium hypochlorite is very toxic to blue-mold spores in solutions free from organic matter.

The effectiveness of a sodium hypochlorite spray as a sterilizing agent for packing equipment was investigated. Blocks one inch square were cut from sides of apple boxes, dipped in a spore suspension, and dried. Washings were made from random samples of these by scrubbing each block for five minutes in 300 cc. sterile water with a sterile stencil brush (22), and the average spore load per square inch determined by plating out portions of the wash water. The remaining blocks were sprayed with a sodium hypochlorite solution (Chlorosan) having 0.08 per cent available chlorine. The blocks were kept in an uncovered dish in a carefully sterilized culture chamber, and at the stated intervals the spore load of random samples was determined. From the results of these tests as given in Table 3 it is computed that 23.9 per cent of the spores remained viable after one hour, 10.7 per cent after four and a half hours, 7.3 per cent after 12 hours, and 3.5 per cent after seven days.

As the blocks used in this experiment were of the cleaner type another brief test of the effect of a sodium hypochlorite solution on

Table 3. Reduction of Number of Viable Blue-mold Spores on Pieces of Apple Box by a Sodium Hypochlorite Spray (0.08 Per Cent Available Chlorine).

Time of series after spraying	Spores per square inch on blocks of each series						
	1	2	3	4	5	6	Average
Unsprayed	128,000	102,000	102,300	70,700	157,300	150,700	118,500
1 hour	11,000	4,000	1,700	16,000	58,000	79,000	28,300
3 hours	2,300	2,300	3,700	54,700	27,000	31,300	20,200
4½ hours	1,000	3,000	1,300	10,000	25,300	35,700	12,700
12 hours	———	———	———	14,300	6,700	6,700	9,200
7 days	———	———	———	0	13,000	0	4,300

[1] Furnished by West Disinfecting Co., Seattle, Washington.
[2] Manufactured by Zonite Products Corporation, New York City.

extremely dirty packing boxes was made. Blocks cut from such boxes from Wenatchee were not dipped in a spore suspension, but were handled and sprayed as in the above series. It was found (Table 4) that only 3.6 per cent of the total flora of the wood blocks remained viable after one hour, and that the killing continued for a considerable period, only 0.5 per cent remaining alive after seven days. Practically all of the fungous spores were killed by the treatment.

Table 4. Reduction of Number of Organisms on Pieces of Dirty Picking Boxes by a Sodium Hypochlorite Spray

Time after spraying	Organisms present per square inch	
	Number	Types
Unsprayed blocks	2,039,700*	Many bacteria and fungi; 5% Penicillium
1 hour	73,300	Numerous bacteria and few fungi
12 hours	74,700	Numerous bacteria and few fungi
7 days	10,500	Numerous bacteria and 2 fungous colonies

* Estimated figure; count of one square centimeter multiplied by area of Petri dish. Other figures are actual counts of plates.

The prolonged toxic action indicated in Tables 2, 3, and 4 is further evidence corroborating the results of Rideal (34), Tilley (37), and others, that killing with chlorine compounds is not always rapid, but may extend over several days.

It would probably be advisable to use a sodium hypochlorite solution having at least 0.4 per cent available chlorine for disinfection of picking boxes and packing houses to insure a margin of safety.

A solution of copper sulphate frequently has been recommended for the disinfection of equipment and store room. Bitting (7) found that spores of *P. expansum* were viable after exposure for 590 days to a 0.5 per cent solution of copper sulphate, but were killed in 21 days in a 1.0 per cent solution.

The results given in Table 5 show that twenty-minute exposures to saturated solutions of copper sulphate do not kill blue-mold spores, although lethal to germ tubes. This marked resistance to copper sulphate would indicate that it is not an effective agent to use for disinfection. Its use is also open to the objection of discoloration of equipment, and of injury to fruit placed in treated picking boxes while moist (see injury in Table 6).

Chemically Treated Wraps

Wraps having a minimum of 1.4 per cent metallic copper as copper sulphate have been used in Oregon since 1930 for prevention of

the spread of Botrytis "nest rot" from pear to pear in the box (11). Wraps treated with zinc sulphate and iron sulphate were found to be less effective.

Marloth (29) believed that the effectiveness of the treatment of citrus fruit with sodium bicarbonate or sodium tetraborate solutions for the prevention of decay caused by *P. digitatum* Sacc. and *P. italicum* Wehmer was due to action on the germinating spores resulting from the concentrated solutions the chemicals formed with moisture on the fruit.

The investigations of Bitting (7) showed that spores of *P. expansum* were viable after an exposure of eight days to mercuric chloride 1-1000, after 590 days in a 0.5 per cent copper sulphate solution, and after 14 days in a 0.2 per cent borax solution, but were killed in 21 days by a one per cent copper sulphate solution and in 14 days by a 0.5 per cent borax solution. It has been shown (3) that non-germinated spores of *P. expansum* are fairly resistant to a 17.8 per cent solution of sodium carbonate, a 0.2 per cent solution of borax, a combination of these two, and to a mixture of equal parts of 3.6 per cent solutions of sodium carbonate and trisodium phosphate.

It was thought that the chemicals in treated wraps might act on the germinating spores of *P. expansum* in the same way as the compounds on the surface of citrus fruit, and thus reduce lenticel infections. An experiment was conducted in 1931 to determine the effectiveness of this method of reduction of decay. As a preliminary to this test a study was made of the resistance of germinated and non-germinated blue-mold spores to toxic agents.

Tests were made to determine the toxicity of copper chloride, copper sulphate, sodium carbonate, sodium bicarbonate, sodium tetraborate, and mercuric chloride to non-germinated spores of *P. expansum.* One-tenth cc. of water suspension of spores from 21-day-old cultures was placed in five cc. of the chemical in a centrifuge tube for the stated period, centrifuged for the last two minutes of the exposure, and the liquid poured off. Ten cc. of sterile distilled water were added, the tube shaken and then centrifuged for two minutes. The wash water was poured off, and a drop of the spore suspension mixed with Brown's synthetic medium was mounted as a hanging drop. The tests were made consecutively on the same day and were held for one week. In another series the spores were slightly germinated in apple juice, a drop of the suspension placed in one cc. of the chemical being tested and treated as above. Each hanging drop was mounted under an individual microscope and several germ tubes selected for periodic examination and measurement.

The results (Table 5) show that mercuric chloride 1-1000 (cf. Bitting, 7) and five per cent copper chloride kill both germinated and

non-germinated spores in five minutes. A saturated solution of ammoniated copper carbonate killed all germ tubes and most of the non-germinated spores in ten minutes. While a saturated solution of copper sulphate killed germ tubes, it was relatively ineffective on non-germinated spores. A saturated solution of sodium carbonate killed germ tubes, and was somewhat more effective than copper sulphate on non-germinated spores. Sodium tetraborate and sodium bicarbonate were relatively ineffective on both germinated and non-germinated spores. The latter two chemicals are effectively used for the treatment of citrus fruit for reduction of decay caused by *P. digitatum* and *P. italicum* (29). Sodium tetraborate stimulates early formation of spores, conidia being formed on germ tubes 16 microns long. Ammoniated copper carbonate, copper chloride, and sodium carbonate were thought to offer the best possibility of the chemicals tested for use in chemically treated wraps.

Winesap apples of the late-maturity picking (October 26, 1931) from the Horticultural Experiment Station orchard in Wenatchee were used in the test, and were held in the ways indicated in a previous publication (4, p. 13) before being wrapped and stored, in order to determine the effectiveness of the treatment and possible injury to fruit handled in different ways. Since the results were comparable for all lots with each type of wrap, only the summarized evidence is presented.

The copper sulphate wraps[1] were those employed commercially for controlling Botrytis rot of pears. The "vitalized oil" wraps[1] were a special product, the exact nature of which could not be determined. The copper chloride and sodium carbonate wraps were prepared by treating ordinary oiled wraps with a concentrated aqueous solution of the chemically pure compound. The wraps were dipped individually and spread out on tables to dry. The copper carbonate, which was a fairly pure product, was made into a paste by the use of ammonium hydroxide; the wraps were dipped in an aqueous solution made from this paste, and were spread out on tables until the ammonia had volatilized. All of the wraps were dried in an oven at 38° C. for several days before being taken into the field. To determine whether such a method of control had any potential value the chemicals in the wraps were used in greater amounts than would be desirable commercially.

The data (Table 6) taken February 19 and March 14, 1932 show that fruit in the five special types of wraps had a lower average percentage of lenticel infection and total blue-mold decay than fruit in ordinary oiled wraps. The wraps treated with copper chloride and copper sulphate produced so much injury to the fruit as to be useless, but the fruit so wrapped had numerous lenticel infections. Wraps treated with sod-

[1] Furnished by Crown-Willamette Paper Co., Portland, Oregon.

Table 5. Germination of Spores and Development of Germ Tubes of *P. expansum* Exposed to Different Strengths of Toxic Chemicals for Various Periods*

Chemical	Strength	Exposed 5 minutes			Exposed 10 minutes			Exposed 20 minutes		
		Spores		Growth germ tubes	Spores		Growth germ tubes	Spores		Growth germ tubes
		Germination	Growth		Germination	Growth		Germination	Growth	
Mercuric chloride	1-1000	0	0	0	0	0	0	0	0	0
Copper chloride	5 or 10%	0	0	—	0	0	—	0	0	—
	Saturated	0	0	0	0	0	0	0	0	0
Ammoniated copper carbonate	Saturated	F	G	0	F	G	0	0	0	0
Copper sulphate	5 or 10%	E	E	—	E	E	—	VG	VG	—
	Saturated	E	E	0	E	E	0	VG	VG	0
Sodium carbonate	5%	VG	VG	—	E	E	—	G	G	—
	10%	0	0	—	0	0	—	0	0	—
	Saturated	F	F	0	0	0	0	F	F	0
Sodium bicarbonate	5%	E	E	—	E	VG	—	E	E	—
	10%	E	G	—	E	VG	—	E	E	—
	Saturated	E	G	F†	E	VG	F†	E	E	F†
Sodium tetraborate	5 or 10%	E	E	—	E	E	—	E	E	—
	Saturated	E	E	F‡	VG	VG	F‡	VG	VG	F‡
Water check	———	E	E	E	E	E	E	E	E	E

* 0 = none ; F — fair ; G — good ; VG = very good ; E = excellent. Tests made in December, 1931.
† About 15 microns in eight hours.
‡ Spore formation began early from short germ tubes.

ium carbonate, "vitalized oil," and copper carbonate, in the order given, appeared most effective of the types tested in reducing lenticel infections and total blue-mold decay; none of these wraps injured the fruit.

The use of treated wraps for the reduction of blue-mold decay is not believed to be commercially practicable. While it reduces decay somewhat, it can never be effective in preventing decay at such injuries as box-cuts and stem punctures in which the spores have been forced into the flesh of the fruit. The wrap is not in sufficiently close contact with the apple that all of the moisture on the fruit surface will contain the dissolved chemical; it is undoubtedly in areas of moisture free

Table 6. Percentage of Lenticel Infections and Total Blue-mold Decay in Winesap Apples Wrapped in Paper Treated with Various Chemicals. Wenatchee, 1931.

Chemical treatment of wrap	Number apples	Per cent blue-mold decay			Condition of fruit	Condition of wraps
		Total	Lenticel infections			
			Certain	Probable		
Copper chloride	403	3.5	2.2	1.0	Severely pitted	Very wet
Copper sulphate	188	3.7	1.1	0.0	Severely pitted	Wet
Copper carbonate	401	3.5	1.7	0.5	Uninjured	Dry
Sodium carbonate	421	1.9	1.0	0.2	Uninjured	Wet and weakened
"Vitalized oil"	183	3.3	1.6	0.0	Uninjured, very waxy	Dry
Total or average of treated wraps	1596	3.1	1.6	0.4	———	———
Ordinary oil wrap	405	5.7	4.0	0.7	Uninjured	Dry

from toxic agents that the lenticel infections occurred. It is to be noted that *P. expansum* does not tend to spread from apple to apple in the box to as great a degree as does *Botrytis cinerea* Pers. on pears, and that the use of treated wraps for reduction of blue-mold decay

would aim at prevention of infection by spores on the fruit rather than control of spread within the container. For that reason the efficiency of the treated wraps in the case of Botrytis rot of pears is no argument for their value in reduction of blue-mold decay.

The application of the agents directly to the apple as is done with citrus fruit, would be more desirable than the use of treated wraps. Further, if the agent were volatile the chances of penetration of box cuts and stem punctures by it would be increased. These conditions are fulfilled in the sodium hypochlorite rinse subsequently discussed.

Treatment of Fruit with Sodium Hypochlorite Solutions

As early as 1895 Kinney (25) suggested that "some simple method of disinfection may be found which will, with proper protection from contamination afterward, considerably prolong the time that apples may be kept in a fresh and edible condition . . ." This is still to be considered the ideal method of control of blue-mold decay, for it would obviate the need of careful sanitation previous to the treatment, and the use of chemically treated wraps, gas storage, etc.

A considerable number of studies have been made on the treatment of fruit with various agents to secure this partial sterilization. Various workers (17, 18, 36) have obtained no reduction in decay by the use of formaldehyde in the washing solution or rinse. Barss (6) obtained a reduction in the amount of decay in cherries and prunes by a formaldehyde dip, but obtained better control by the use in both the bottom and top of boxes of a paper impregnated with formaldehyde. A rinse with an unspecified proprietary sodium hypochlorite solution was found to be useless in control.

The use of hypochlorite solutions for the treatment of fruit has received little attention from scientific investigators, although a commercial treatment with this chemical is now in use in California and Texas citrus packing plants. Friend and Bach (14) found that this Hypo-Clor process was of no particular benefit in reduction of decay of grapefruit in Texas under the conditions of the test. However, only slight amounts of blue-mold decay were recorded in their investigations.

In the Hypo-Clor treatment[1] the fruit is moved through a long tank containing a sodium hypochlorite solution having 0.4 per cent available chlorine; forward movement is accomplished by paddles which submerge the fruit slightly. A light spray of water and drying of the fruit follow. The liquid is obtained by chlorination of a solu-

[1] According to communications from J N. Sharma, Chief Chemist of the Food Machinery Corporation, San Jose, California.

tion containing sodium carbonate and sodium hydroxide. The process was used in 21 citrus packing houses in California and two in Texas in 1932. To date no tests have been made with this process on apples.

A number of tests were undertaken in 1931, 1932, and 1933 to determine whether a sodium hypochlorite treatment would be effective in the reduction of the blue-mold decay of apples. These will be discussed in two sections: (1) reduction of spore load of the fruit; (2) reduction of blue-mold decay.

Apples from the Horticultural Experiment Station orchard in Wenatchee were dipped in a suspension of blue-mold spores and allowed to dry. Half of this lot was then dipped in a sodium hypochlorite (Chlorosan) solution having 0.08 per cent available chlorine. The Jonathan and Delicious apples were treated on September 26 and the Winesaps on October 17, 1931. These two lots were then packed and held in cold storage. On November 30, 1931 washings were made from three uniform-sized apples of the treated and untreated Jonathan and Delicious lots by the method of Huber (22); the Winesaps were analyzed in the same way on January 25, 1932. Each of the figures in Table 7 is the average of three poured plates from the water in which the fruit was washed, transposed to indicate the number of viable organ-

Table 7. Number of Colonies of Organisms from Apples Dipped in Water or in a Sodium Hypochlorite Solution for One Minute. Wenatchee, 1931*

Variety	Apple number	Dipped in water		Dipped in sodium hypochlorite	
		Number	Types of fungi	Number	Types of fungi
Jonathan	1	110,000	Mostly P	6,000	No P, few C
	2	160,000	Many P, D	50,000	100 P, few C
	3	87,000	Mostly P, few D	4,000	390 P; few A, C
	Average	119,000	Many P, D	30,000	163 P; few C, A
Delicious	1	50,000	Many P, D	99,000	Few P; many C
	2	747,000	Few P, many D	54,000	Few P; numerous A, C
	3	532,000	Few P, many D	71,000	Very little P, mostly D
	Average	443,000	Numerous P, many D	74,667	Few P; numerous D, A, C
Winesap	1	33,300	800 P, few C, mostly D	2,100	No P, mostly D
	2	33,900	300 P, mostly D	0	———
	3	19,800	600 P, mostly D	500	400 P, 100 D
	Average	29,000	566 P, many D	867	133 P, numerous D

* P = **Penicillium expansum**; D = Dematium spp.; C = Cladosporium spp.; A = Alternaria spp.

Table 8. Reduction of Number of Spores of *P. expansum* per Apple by Dipping in Solutions of Sodium Hypochlorite of Various Strengths for One Minute*

Apple number	Water check		Per cent available chlorine in NaOCl solutions used							
			0.08		0.15		0.20		0.25	
	Blue-mold spores	Other organisms	Blue-mold spores	Other organisms	Blue-mold spores	Other organisms	Blue-mold spores	Other organisms	Blue-mold spores	Other organisms
1	21,000	Many C, D	11,000	Few C, many D	4,000	Few C, numerous D	1,000	Few C, D	2,000	Many C, few D
2	12,000	Few C, many D	6,000	Numerous C, D	24,000	Few D	4,000	Many C, few D	0	Many C, few D
3	18,000	Few C, many D	28,000	Few D	1,000	Few C, many D	2,000	Few C, numerous D	1,000	Numerous C, D
4	14,000	Few C, many D	———	———	———	———	———	———	———	———
5	34,000	Few C, many D	———	———	———	———	———	———	———	———
Average	19,800	——	15,000	———	9,667	———	2,333	———	1,000	———

* February 26, 1932. C = Cladosporium spp.; D = Dematium spp.

isms per apple at the time of the test. The results indicate a marked reduction of the spore load by the brief treatment with dilute sodium hypochlorite. The number of viable spores of *P. expansum* was greatly reduced; Cladosporium and Dematium were more abundant, possibly because of the sporulation on the apples after treatment. It is to be noted that the concentration of, and time of exposure to, the sodium hypochlorite solution were much lower than those employed in the citrus industry.

Another test, using Winesap apples from the same source, was conducted in 1932 (Table 8). The fruit was dipped in a spore suspension, and the method of analysis was the same as in the preceding lot. The untreated apples had an average of 19,800 viable spores of *P. expansum*, whereas those treated with Clorox solutions having 0.25 per cent available chlorine had 1,000 viable spores. In this series there were also many viable spores of Cladosporium and Dematium following the treatment.

Kidd and Beaumont (24) reported that washing apples with mercuric chloride did not kill the fungous spores in the lenticel basins. A brief test was made to determine whether sodium hypochlorite solutions were lethal to spores in such a position.

The fruit was from a Selah orchard (4, p. 9, lot 3), and was picked and dipped in a spore suspension on September 22, 1932. Two days later half were dipped in water for one minute, and half dipped in a solution of Clorox having 0.4 per cent available chlorine, before being packed. On December 20, 1932 these two lots were examined in cold storage for the amount of decay (Table 9).

Random samples of each of these lots were taken for determination of the comparative spore load of the lenticels. Using a small half-spear scalpel, lenticels were cut from the apples in such a way that

Table 9. Percentage of Reduction of Blue-mold Decay in Jonathan Apples by Dipping in a Sodium Hypochlorite Solution for One Minute.

Fruit dipped in water				Dipped in Clorox (0.4 per cent)			
	Per cent blue-mold decay				Per cent blue-mold decay		
Number apples	Total	Lenticel infections		Number apples	Total	Lenticel infections	
		Certain	Probable			Certain	Probable
83	15.7	7.2	3.6	75	6.7	4.0	0

very little of the surrounding epidermis was included. These were then placed on fairly soft, two per cent dextrose potato-agar with the pointed end imbedded in the medium. Lenticels having the fungus present would soon show it developing on the lenticel surface and spreading to the medium. The results (Table 10) show a decrease of 89.6 per cent in the number of lenticels containing spores, as a result of the treatment.

Table 10. Number of Lenticels of Jonathan Apples of Table 9 Containing Blue-mold Spores

Apple number	Series dipped in water			Series dipped in sodium hypochlorite		
	Number lenticels isolated			Number lenticels isolated		
	Total	With blue-mold spores	With spores of other fungi	Total	With blue-mold spores	With spores of other fungi
1	17	1	1	18	0	0
2	18	2	2	20	0	0
3	17	10	0	18	0	0
4	20	15	0	18	3	0
Average	18	7	0.8	18.5	0.8	0

These preliminary investigations showed marked reduction in the number of blue-mold spores, both in lenticel basins and on the surface of the fruit, as a result of treatment with sodium hypochlorite solutions. The following series show the effectiveness of the treatment for reduction of decay.

Winesap apples were obtained from the Horticultural Experiment Station orchard in Wenatchee in 1932 for the series shown in Tables 11 and 12. Some of this fruit was punctured with a special stick in three places per apple, the holes being four millimeters in diameter or about like a stem puncture. The apples were then run through the Experimental Fruit Washer (16) with hydrochloric acid or sodium carbonate in the washing tank, which was uniformly contaminated with an abundance of blue-mold spores with each change of solution. The prewash tank was omitted. The first rinse in all cases was with clean water, as practiced commercially. The second rinse was either with water or a Clorox solution having 0.4 per cent available chlorine, as indicated. The fruit was packed at once (October 19 and 21), and held in cold storage. Examination on February 21-28, 1933 (Table 11) showed marked reductions in the percentage of punctures at which decay had started, as a result of the sodium hypochlorite treatment following either hydrochloric acid or sodium carbonate. The examina-

Table 11. Percentage of Reduction of Decay in Punctured Winesap Apples as a Result of Action of a Sodium Hypochlorite Rinse. Wenatchee, 1932

Solutions in tanks			Total number of punctures	Per cent of punctures infected with blue mold	
Washing tank 43° C.*	First rinse	Second rinse		First examination	Total, first and second examinations
Hydrochloric acid	Water	Water	234	19.7	29.5
Hydrochloric acid*	Water	NaOCl	504	3.1	4.6
Sodium carbonate	Water	Water	234	21.4	22.6
Sodium carbonate	Water	NaOCl	501	8.2	20.0

* Hydrochloric acid used at one per cent strength; sodium carbonate used at 75 pounds per 100 gallons.

tion on July 25 and 27 showed a similar condition for the fruit washed in acid but a very different result for that washed in sodium carbonate. This latter condition can best be explained by accidental reinoculation of the wounds in the handling of the first examination; it is improbable that these were incipient infections at the time of the first examination (four months after the fruit was inoculated). These first figures are the ones which would be significant from the standpoint of commercial control. It is apparent that the treatment gives a transitory protection and does not influence infection from subsequent contamination. Since commercially packed fruit is not subjected to contamination until it is unpacked for consumption, this partial sterilization is capable of greatly reducing decay.

In practically every case the punctures so inoculated yield pure cultures of *P. expansum*. This is due to the preponderance of blue-mold spores in the inoculum and to the inhibiting effect the development of the organism has on most other apple-rotting fungi. Machacek (28) found that apple decay caused by *P. expansum* in the storages in the vicinity of Montreal nearly always yielded pure cultures. Similar results have been obtained from time to time by various investigators at this station. Machacek found that several fungi would not develop in areas of fruit decayed by the Penicillium or in cultures staled by it. and that this dominance of growth was affected by temperature and by spore concentration. In this, and in succeeding tests with punctured fruit, this comparatively crude method of inoculation is considered to give very little contamination by other fungi. When infections with other fungi did occur they were readily detected by symptoms, and so recorded.

Some of the lot of fruit used in Table 11 was handled in the same way, except that it was not punctured. The results taken July 25 and

27 (Table 12) show that fruit rinsed in sodium hypochlorite had less blue-mold decay than untreated fruit. As there were almost no lenticel infections in this lot of fruit no significant results on control of decay starting at that point were obtained.

Table 12. Percentage of Reduction of Blue-mold Decay in Winesap Apples as a Result of Action of a Sodium Hypochlorite Rinse. Wenatchee, 1932

Solutions in tanks			Number apples	Per cent blue-mold decay		
				Total	Lenticel infections	
Washing tank 43° C*	First rinse	Second rinse			Certain	Probable
Hydrochloric acid	Water	Water	284	4.2	0	0.7
Hydrochloric acid	Water	NaOCl	574	1.4	0	0.3
Sodium carbonate	Water	Water	297	5.7	0.3	0.3
Sodium carbonate	Water	NaOCl	575	3.1	0.3	0.9

* Hydrochloric acid used at one per cent strength; sodium carbonate used at 75 pounds per 100 gallons.

A test was made in 1932 to determine the effect of submersion in a sodium hypochlorite solution on the amount of decay shown in Delicious and Winesap apples from the Horticultural Experiment Station orchard in Wenatchee. One lot of each variety was submerged for five minutes in two and a half feet of a water suspension of blue-mold spores. Another lot of each was submerged for five minutes in a spore suspension in a sodium hypochlorite solution (Clorox) having 0.25 per cent available chlorine. These lots were treated April 22, 1932 and held at 10-15° C. until May 14, when data were taken. The results (Table 13) show a reduction in total blue-mold decay due to the sodium hypochlorite treatment.

Table 13. Percentage of Reduction of Blue-mold Decay in Apples from Submersion in a Sodium Hypochlorite Solution. 1932

Variety	Treatment	Number apples	Per cent blue-mold decay		
			Total	Calyx	Lenticel infections
Delicious	Water plus spores	40	90.0	7.5	22.5
	NaOCl plus spores	31	64.5	0.6	16.1
Winesap	Water plus spores	82	18.3	1.2	2.4
	NaOCl plus spores	64	9.4	6.3	3.1

In 1933 a test was conducted repeating that of 1932 on the use of a hypochlorite solution in tandem with the washing program (Table 14). Jonathan and Delicious apples from the Horticultural Experiment Station orchard were punctured as in the previous series before being used in the test. The experiment employed the Washington Experimental Fruit Washer (16), water at 43° C. being used first and then the cleaner being added; thus a check was run for each of the cleaners tested. The prewash tank was used with clean water in all cases. The washing tank was uniformly contaminated with an abundance of blue-mold spores with each change of solution. A water rinse or a Clorox solution having 0.4 per cent available chlorine was used in the last

Table 14. Percentage of Reduction of Blue-mold Decay in Punctured Apples as a Result of the Action of the Washing Solution and the Sodium Hypochlorite Rinse. Wenatchee, 1933*

Solutions in tanks			Punctures		Per cent reduction in decay from action of:	
Washing tank 43° C.†	First rinse	Second rinse	Number	Per cent decay	Sodium hypochlorite rinse	Cleaning solution
			Jonathan apples			
Water‡	Water	Water	414	74.2		
Water‡	Water	NaOCl	414	64.3	9.9	
Hydrochloric acid‡	Water	Water	414	29.7		44.5
Hydrochloric acid‡	Water	NaOCl	414	6.3	23.4	
Water**	Water	Water	408	93.4		
Water**	Water	NaOCl	405	87.7	5.8	
Sodium silicate**	Water	Water	408	40.2		53.2
Sodium silicate**	Water	NaOCl	408	6.4	33.8	
			Delicious apples			
Water‡	Water	Water	264	77.3		
Water‡	Water	NaOCl	264	65.2	12.2	
Hydrochloric acid‡	Water	Water	264	20.8		56.5
Hydrochloric acid‡	Water	NaOCl	264	3.8	17.0	
Water**	Water	Water	330	66.4		
Water**	Water	NaOCl	333	57.4	9.0	
Sodium silicate**	Water	Water	330	45.5		20.9
Sodium silicate**	Water	NaOCl	333	0.3	45.2	

* Data taken December 12 and 13, 1933.

† Hydrochloric acid used at one per cent strength; sodium silicate used at 80 pounds per 100 gallons.

‡ Lot treated and packed October 3, 1933.

** Lot treated and packed September 29, 1933.

rinse tank. All lots treated with a hypochlorite rinse showed a marked reduction of the percentage of punctures in which decay started. It is significant that this decrease is greatest in all cases when the hypochlorite rinse followed a washing solution. This is thought to be a result of the decrease in the amount of organic matter, material known to markedly reduce the effectiveness of chlorine compounds. The reduction of decay was greatest in each case where the fruit had just been washed in sodium silicate.

Barger (5) reported that sodium silicate was about as effective as sodium tetraborate in retarding the blue and green molds of oranges. Heald (21) found in brief tests that sodium silicate was effective in reducing blue-mold decay of apples. The data in Table 14 further show the comparative efficiency of hydrochloric acid and sodium silicate cleaners in the reduction of decay. In the Jonathan variety the sodium silicate was the most effective, giving a 53.2 per cent reduction in decay against a 44.5 per cent reduction from the use of hydrochloric acid. With Delicious apples the case was reversed, there being 20.9 per cent reduction from the use of sodium silicate and 56.5 per cent from hydrochloric acid. It is thought that sodium silicate is not to be considered as an effective agent for prevention of decay of apples if the inoculum is kept at a high level.

The decrease of decay in these tests caused by the action of the cleaning agent is greater than that resulting from the sodium hypochlorite solution. This is caused by two factors: (1) the spores were placed directly in the washing solution, whereas the spores were already in the flesh of the apple and relatively inaccessible when exposed to the hypochlorite solution; (2) the exposure of the spores to the cleaning solution occurred throughout the test, whereas the exposure to the hypochlorite was for but 41 seconds (i. e. the time required to pass through the flood-wash of the solution). The efficiency of the partial sterilization in reducing decay is, therefore, thought to be of greater value than the figures would indicate. Further, the reduction of decay by the cleaner represents a level we cannot lower without the use of some such treatment as that tested.

The combined action of the washing solution and the sodium hypochlorite treatment in reducing infections at punctures is summarized in Table 15. These results indicate that a rinse in a sodium hypochlorite solution following the washing treatment is an effective way of reducing blue-mold decay. This process should be regarded as an adjunct to, rather than a substitute for, the avoidance of injuries to the fruit, since such blemishes in themselves lower quality and are likely to become inoculated subsequently (See Table 11). In all of the tests no injury to the fruit from the hypochlorite rinse has been found, except for a slight discoloration around the punctures. The

very slight residue of salts left on the fruit after the chlorine has volatilized does not impair the flavor or the appearance of the fruit.

Table 15. Summary of Percentage of Reduction of Blue-mold Decay from the Action of Washing Solution Plus Sodium Hypochlorite Treatment; Taken from Table 14

Solution in tanks		Per cent of punctures with blue-mold decay	
Washing tank	Second rinse	Jonathan	Delicious
Water	Water	74.2	77.3
Hydrochloric acid	NaOCl	6.3	3.8
Water	Water	93.4	66.4
Sodium silicate	NaOCl	6.4	0.3

Probably the most economical method of application would be by flotation through a tank, keeping the fruit in motion by friction with an overhead, moving, reinforced canvas belt. This belt could be fitted tightly enough at the edges of the tank to greatly reduce the volatilization of the chlorine from the large surface of liquid. The use of a spray or flood wash of the solution at the front end of tank might be desirable in order to insure penetration of injuries and wounds.

The alkaline hypochlorite solutions tend to react on the hands in such a way as to make them slippery, and in time might tend to be injurious to the operators. For this reason a final treatment of the fruit with long-fiber, overhead brushes would be desirable to remove the excess solution.

PREVENTION OF BLUE-MOLD DECAY

In the light of present information the program for reduction of the incidence of blue-mold decay should be of two types: (1) general practices applied to all fruit; (2) special treatments applied to fruit of grower-lots which have a consistently large amount of decay over a period of years. Care in maintaining proper storage conditions, in avoidance of injuries, and in sanitation should always be emphasized. The special treatment should supplement the general methods of control in cases where the general practices are inadequate to satisfactorily solve the blue-mold problem. The various practices of value in prevention of blue-mold decay may be enumerated as follows:

General Practices

Storage Conditions. Apples should be stored at about 0° C.[1] and 85 to 88 per cent relative humidity. The use of gases such as ozone (26), carbon dioxide (10), ammonia (38), and acetaldehyde (15) in storage rooms is of doubtful value because of the slight inhibitory effect of the chemicals on the organism, the difficulty of retaining the gas in the storage rooms, the expense, and in some cases (e. g. ammonia) the injury to the apples.

Avoidance of Injuries. Considerable attention should be given to the reduction of mechanical injuries and bruises in orchard handling. Fruit should be picked when mature; delayed picking increases the number of open lenticels and the susceptibility of the apples to injury (4). Bruises should be avoided because the lenticels in the margins of such injuries are quite susceptible to infection. Some of the conditions to be considered in reduction of injuries are: have pickers keep their finger nails clipped; pick fruit with a twisting motion; avoid dropping or throwing fruit into the picking container, and from it into the box; discard windfalls and fruit dropped on the ground in picking; move ladders carefully to avoid the injury of fruit on the tree; use picking buckets instead of bags to prevent pressing of the fruit against the ladder or tree; avoid picking boxes with nails, slivers, etc., likely to puncture the fruit; cover crops in the orchard reduce the amount of gravel and dirt getting into the bottom of boxes, with its attendant injury; if special picking boxes are used, those with solid bottoms should be given preference; avoid heaping fruit in picking boxes; handle boxes carefully in decking and hauling from the orchard; use insecticides which are non-injurious to fruit, or use neutralizing substances with them (e. g. hydrated lime in arsenical sprays). Avoid letting fruit stand in the orchard during rainy weather, as such treatment favors infection (4).

Avoidable injuries may occur during washing, grading, sizing, and packing. A number of practices which will reduce such injuries are: careful unloading and stacking of fruit on receiving platform; use of dumping aprons for emptying boxes onto washer receiving-belt; holding fruit for long periods in the orchard increases the frequency of injury by hastening maturity, shorter periods may, however, actually reduce the number of susceptible lenticels (4); do not hold fruit in cold storage previous to washing in heated solutions (4); avoid "stacking" and crowding of fruit in the washing machine and on conveyor belts; avoid projecting rough edges, nails, slivers, unnecessary drops or gravity runs, and hard or unprotected receiving surfaces in

[1] Fruit of certain varieties (e.g. Yellow Newtown), or from certain localities (e.g. Pajaro Valley of California) should be held at slightly higher temperatures to prevent internal browning.

handling equipment; practice rigid sorting of fruit to eliminate injured specimens; have sorters clip their finger nails; discard packing gloves when wax-nodules begin to form in the palm; the use of one of the special marketing containers which reduce handling injuries might be desirable; pack fruit tightly to avoid "rattlers"; use two-piece lids and bottoms in boxes; avoid close, high, slow-cooling stacks of packed boxes in cold storage. In the washing process avoid machines which employ submersion or jetspray principles; titrate cleaning solutions to maintain the proper strength; use a continuous-change type of rinse, possibly one containing a neutralizing agent (hydrated lime or hydrochloric acid, depending on whether acid or alkaline solutions are used in cleaning); do not use the washing solutions at temperatures of over 43° C., or at the most 49° C. (4, 13, 20).

Sanitary Practices. Since the orchard is the first source of fungous contamination of the fruit, sanitation at this point is important. The inoculum may be reduced by burying all fallen fruit before it decays, and by avoiding the interplanting of apples and pears, because the latter drops early and decays rapidly. Avoid the use of old dirty picking boxes, or sterilize them by spraying with a sodium hypochlorite solution having at least 0.4 per cent available chlorine and holding for a few days in a room protected from air currents.

The packing plant is the principal source of contamination of fruit, and is the most strategic point for practicing sanitation. General practices for reduction of the population of blue-mold spores should include the removal of refuse (e. g. leaves, spurs, rotten fruit, etc.) at regular intervals from the packing plant. Spraying of the walls, floor, ceiling, and of much of the equipment with a sodium hypochlorite solution having about 0.4 per cent available chlorine is recommended. Because of its low toxicity for *P. expansum*, copper sulphate should not be used for this purpose.

The washing tank is one of the main sources of contamination of apples because, directly or indirectly, it receives inoculum from nearly all of the sources mentioned. Partially rotted apples should not be allowed to pass into the washing tank. A continuous-flow prewash of water would be of value in reducing the spore load of fruit before entering the washing tank. Special sterilization of the washing tank during the overnight stand has been shown (3) to be unnecessary with present conditions of operation, since the solutions are sufficiently toxic to kill nearly all the spores during that time.

Special Chemical Treatment

This type of control has been used to kill the spores on the surface of the fruit (i. e. give partial sterilization), or to inhibit their

germination at a later period. Sodium tetraborate and sodium bicarbonate are employed in the citrus industry for the latter purpose, but their low toxicity to *P. expansum* precludes their use on apples. The low toxicity of copper sulphate for the organism would explain why Bordeaux mixture and copper sulphate treatments are not very effective (12). It has been shown (19) that the Brogdex paraffin-oil mixture is valueless in the reduction of decay. Formaldehyde has not proved satisfactory for fruit disinfection.

The treatment of apples for at least one minute in a sodium hypochlorite solution having 0.4 per cent available chlorine is recommended as an effective partial sterilization. The most economical method of application of this treatment would probably be by the introduction of a combination flotation-tank and spray-rinse of the solution following the regular rinse of present machinery.

The methylene blue dye test and the decayed tissue test are potentially valuable indices of the susceptibility of a given lot of fruit to lenticel infections (4). At present it probably would be more economical to always treat lots which have had a consistently large amount of decay over a period of years, than to attempt to restrict the treatment by the use of these indices.

A brief exposure of the fruit to warm dry conditions to decrease the number of lenticels susceptible to infection (4)[1] may be found to be an effective way of reduction of blue-mold decay.

The use of chemically treated wraps is not an effective method of prevention of blue-mold decay. Orchard spraying for decay prevention is impracticable because the compound would be washed off before packing and would not protect fruit when most needed; it has been shown to be ineffective on cherries and prunes for this purpose (9). Although there are differences in varietal susceptibility to both lenticel infection (4) and rate of advance of decay lesions, these are not great enough to be of value from the standpoint of control of blue-mold decay.

[1] The unpublished investigations of Dr. H. F. Clements in the Department of Botany further show the effect of warm dry conditions on the lenticels.

SUMMARY

1. The contamination of blue-mold spores on picking boxes and packing equipment increases greatly during the harvest season, and to a lesser extent from season to season, because of the longevity of the spores and the ability of the fungus to develop and sporulate on these substrata under field conditions. Only by disinfection can the number of viable spores be kept at a low level.

2. As copper sulphate solutions are not effective in killing blue-mold spores, their use in the sterilization of apple storage rooms, bins, etc., should be discontinued.

3. Sodium hypochlorite solutions are extremely toxic to spores of *P. expansum*. Sprays of such solutions having about 0.4 per cent available chlorine would be very effective in the disinfection of picking boxes and packing equipment. The toxic action of this compound continues under some conditions for several days.

4. The use of chemically treated wraps for the control of blue-mold decay is not as desirable as direct treatment of the fruit with the toxic agent.

5. Sodium bicarbonate and sodium tetraborate, although markedly toxic to *P. italicum* and *P. digitatum*, are relatively innocuous to *P. expansum*. Their use in the treatment of apples by methods similar to that used for citrus fruit is, therefore, not recommended. Neither is sodium carbonate sufficiently toxic to be valuable for this purpose.

6. Treatment of apples with a sodium hypochlorite rinse is very effective in reducing the spore load of the surface of the fruit and the lenticel basins, and in decreasing the percentage of decay at punctures and other points of entry. The fruit should be exposed for at least one minute to a solution having 0.4 per cent of available chlorine. The hypochlorite rinse is most effective when it follows the washing process. The treatment is not injurious to the fruit, and the slight deposit of salts left on the surface does not impair the flavor or appearance.

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